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Multiple Antenna Integration in Small Terminals

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Abstract

The Theory of Characteristic Modes (TCM) can be effectively used for the realization of both, multistandard antennas and multiport antenna systems on small terminal platforms. For multistandard applications simultaneous excitation of multiple modes is desired while multiport antenna systems for MIMO require the selective excitation of orthogonal modes. Both cases require different coupling strategies. Capacitive couplers enable the simultaneous excitation of modes while inductive coupling elements provide advantages with respect to the selective excitation.

1 Introduction

Future mobile terminals require operation in multiple standards associated with multiple frequency bands. In addition advanced standards, like LTE (Long Term Evolution) and IEEE 802.11n require the integration of multiple antennas with uncorrelated properties. Both requirements can hardly be achieved with standard multi-resonant PIFA or monopole concepts mainly because of the small form factor of small terminals.

An elegant approach to address both challenges is based on the excitation of different modes of the small terminal chassis itself and utilization the antenna functionality of these modes. The realization of such concepts is based on the so-called Theory of Characteristic Modes (TCM) in combination with concepts for coupling elements enabling the excitation of these modes including impedance match to the 50 Ω front-end impedance.

2 The Theory of Characteristic Modes

The current density distribution on the surfaces of a conductive plate, such as the PCB (Printed Circuit Board) of a mobile terminal, can be decomposed into a set of characteristic modes [1]:

$$\mathbf{J} = \sum_n \alpha_n \mathbf{J}_n = \sum_n \frac{V_n^i}{(1 + j\lambda_n)} \mathbf{J}_n \quad (1)$$

The entire current density of the surface in (1) is equal to the sum of the weighted orthogonal functions of the characteristic current modes J_n. In (1) α_n denotes the weighting coefficient and V_{ni} denotes the excitation coefficient, which describes the influence of the external excitation on the *n*-th characteristic current mode of the entire current distribution. Later, in an antenna system the excitation coefficient determines how effective a particular characteristic current mode is excited by the coupling element.

Figure 1 shows the eigenvalues of some characteristic modes of a rectangular plate having typical dimensions of a small terminal chassis. It can be observed that in the low frequency range around 1 GHz only one mode is dominant, i.e. its eigenvalue is low. The resonance frequency of this mode is close to 1.1 GHz. Efficient excitation of a characteristic mode is easier close to its resonant frequency where its eigenvalue is sufficiently low. It can also be observed from Figure 1 that in the higher frequency range above 2 GHz several modes provide sufficiently low eigenvalues, i.e. their excitation is easily possible.

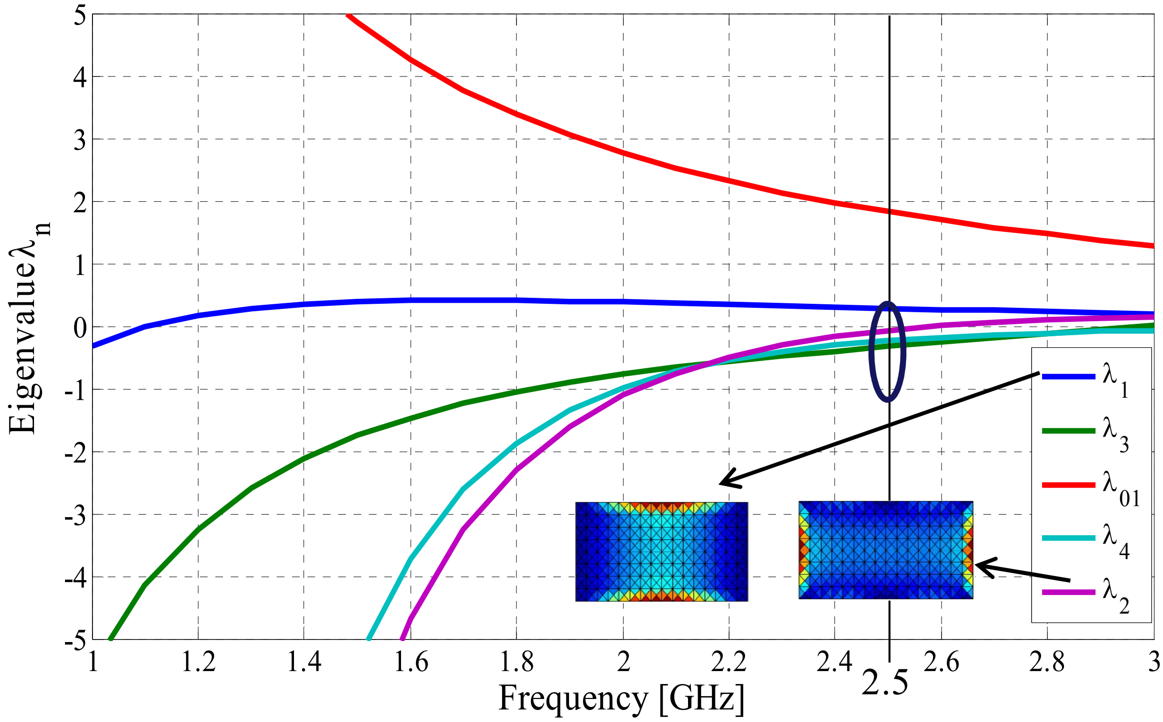


Figure 1: Eigenvalues of some characteristic modes of a rectangular metal plate (120 mm × 60 mm).

Distribution wise, e.g. mode 1 is the $\lambda/2$ dipole mode along the long axis of the plate while mode 2 is the $\lambda/2$ dipole mode along the short axis. Other modes provide higher order distributions.

3 Application to Multistandard- and Multiport Antennas on Small Terminals

Basically, the current distribution on the chassis determines the antenna functionality of the small terminal. The more effective the coupling element excites the characteristic modes of the chassis the more effective the antenna of the terminal is [2].

In principle, the characteristic modes enable two different applications with respect to future mobile terminals. If a broadband or multiband antenna is desired we aim at exciting as many modes as possible within the desired frequency range. If a multi antenna system on a small terminal is desired we aim at exciting different modes with different coupling elements selectively. In this respect it is very appealing for MIMO applications that according to the TCM the radiated far fields of different modes are orthogonal to each other.

Figure 2 illustrates both principles, the simultaneous excitation and the selective excitation. In order to develop a multi standard antenna a single coupling element that excites multiple modes is used. A multi antenna systems based on this concept combines different coupling elements at different antenna ports.

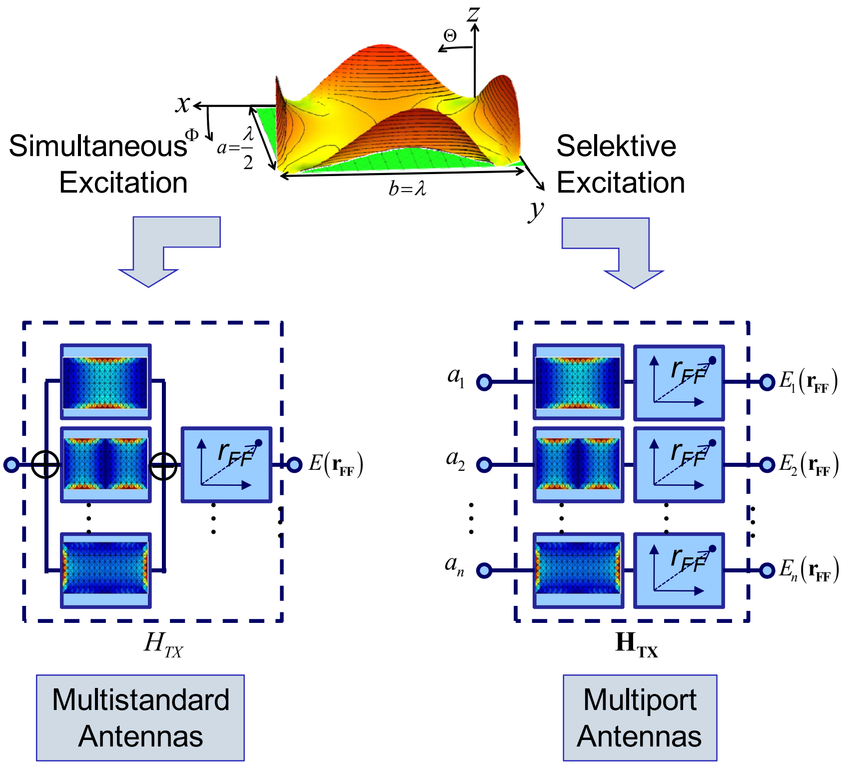


Figure 2: Application of the TCM for multistandard- and multiport antennas.

3.1 Multistandard Applications

In order to excite multiple modes simultaneously capacitive coupling elements are best suited as they can be placed at the corners of the chassis where all modes have common voltage maxima [3].

Figure 3 shows the application of the principle to realize a configurable multi standard antenna on a small terminal. A capacitive coupling element is located at the top edge of the chassis. Because of the frequency dependence of the modes as shown in Figure 1, a reconfigurable matching network has to be used. The network is realized in a compact LTCC component with embedded GaAs MMIC SP8T switch. Details are presented in [4]. It has been shown that all relevant standards can be covered with reasonable total efficiency.

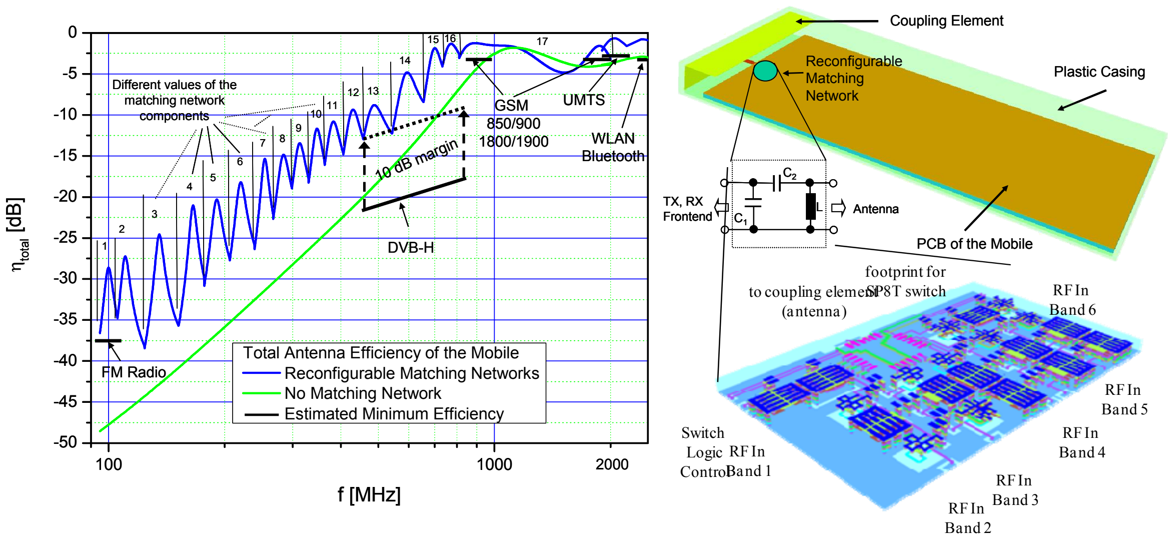
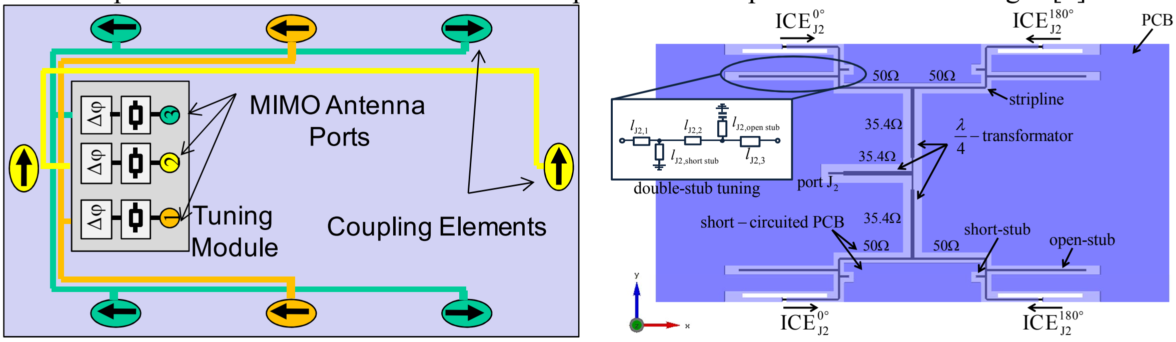


Figure 3: Simultaneous excitation of modes by a capacitive coupling element and a reconfigurable switchable matching network.

3.1 Multiport Antennas for MIMO Applications

In order to utilize the TCM for the realization of multiport antennas for MIMO applications we aim at the selective excitation of different modes. For the selective excitation inductive coupling elements placed in the current maxima of the respective modes provide some advantages [3].



a) Concept for selective excitation using three sets of couplers and a tuning network.

b) Realization of set 2 (green in figure 4a) and distributed tuning network.

Figure 4: Multiport antenna concept using different sets of couplers for the selective excitation of modes.

Table 1 shows the cross correlation between the desired modal far field and the entire far field obtained by feeding the different antenna ports. It can be observed that the desired modes are excited with reasonable purity.

TABLE 1

CROSS CORRELATION BETWEEN THE DESIRED MODE AND ENTIRE RADIATION PATTERN FOR THE REAL ICE_{JN} - ANTENNA

$\lvert\rho_{J1,\,ICE\ J1\text{-}Antenna}\rvert$	$\lvert\rho_{J2,\,ICE\ J2\text{-}Antenna}\rvert$	$\lvert\rho_{J3,\,ICE\ J3\text{-}Antenna}\rvert$
0.8082	0.9767	0.7622

4. Conclusion and Outlook

It has been shown that the Theory of Characteristic Modes can be effectively used for the realization of both multistandard antennas and multi antenna systems on small terminals. In both cases a small form factor can be achieved as the entire chassis is utilized as the antenna while the coupling elements itself are electrically small. Future work aims at compact realizations of the tuning module of the multiport antenna.

References

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